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PROTOTYPE VEHICLE PERFORMANCE SPECIFICATION

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AGENCY

PROTOTYPE VEHICLE PERFORMANCE SPECIFICATION

January 3, 1972

Division of Advanced Automotive
Power Systems Development

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Ann Arbor, Michigan 48105

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ADVANCED AUTOMOTIVE POWER SYSTEMS (AAPS)

PROTOTYPE VEHICLE PERFORMANCE SPECIFICATION *

January 3, 1972

The AAPS Vehicle performance design specification presented below is intended to provide:

A common objective for prospective contractors.

Criteria for evaluating proposals and selecting a contractor.

Criteria for evaluating competitive power systems for entering first generation system hardware.

Advisory criteria to assist the contractor in such areas as rolling resistance, vehicle air drag etc.

The derived criteria are based on typical characteristics of the class of passenger automobiles with the largest market volume produced in the U.S. during the model years 1969 and 1970. It is noted that emissions, volume and most weight characteristics presented are maximum values while the performance characteristics are intended as minimum values. Contractors and prospective contractors who take exceptions must justify these exceptions and relate these exceptions to the technical goals presented herein.

*Supersedes "Vehicle Design Goals - Six Passenger Automobile" (Revision C - May 28, 1971)

CONTENTS

	SECTION	PAGE
Introduction	-	3
Vehicle Weight Without Propulsion System	1	4
Propulsion System Weight	2	4
Vehicle Curb Weight	3	4
Vehicle Test Weight	4	4
Gross Vehicle Weight	5	5
Propulsion System Volume	6	5
Air Drag	7	5
Rolling Resistance	8	5
Propulsion System Emissions	9	6
Fuel	10	6
Start Up, Acceleration and Grade Velocity Performance	11	7,8
Minimum Vehicle Range	12	9
Fuel Consumption	13	9
Accessory Power Requirements	14	10
Propulsion System Operating Temperature and Pressure Range	15	10
Passenger Comfort Requirements	16	10
Noise Standards	17	10
Operational Life	18	11
Reliability and Maintainability	19	11
Cost of Ownership	20	11
Safety Standards	21	11

Test Conditions Table I

INTRODUCTION

The design of an automobile from a total systems standpoint could be expected to result in major benefits in cost, safety, and performance. This specification is intended as a step along that path, describing a propulsion system that can be installed into engine compartments as they now exist. Integration of the vehicle accessories within the propulsion system are highly desirable. Following the successful demonstration of this development further optimization of the propulsion system with the power train, suspension, and vehicle styling would be possible.

1. VEHICLE WEIGHT WITHOUT PROPULSION SYSTEM - W_o

W_o is the weight of the vehicle excluding the propulsion system. This weight includes, but is not limited to the frame, body, glass, trim, suspension, wheels (rims and tires), service brakes, seats, upholstery, sound absorbing materials, insulation, dashboard instruments, accessory ducting and wiring, accessories, and all other components not included as part of the propulsion system.

Accessories are defined as driver assistance and passenger convenience components and subsystems not essential to propulsion system operation. Included are power steering systems, power brake systems and passenger compartment heating and air conditioning systems.

W_o is fixed at 2700 lbs.

2. PROPULSION SYSTEM WEIGHT - W_p

W_p includes the energy storage subsystem (including fuel, containment, and supply and deliver ducting), power conversion subsystem (including auxiliaries and control) and power transmitting subsystem (including transmission and drive train to the driven wheels).

Auxiliaries are defined as components and subsystems essential to the operation of the power conversion system. Included are electric power generating subsystems, starting subsystems, exhaust subsystems, motors fans, blowers, pumps, and fluids.

Lightweight propulsion system are highly desirable, however, the maximum allowable propulsion system weight, W_{pm}, is 1500 lbs.

3. VEHICLE CURB WEIGHT - W_c

$W_c = W_o + W_p$.

The maximum allowable vehicle curb weight, W_{cm}, is 4200 lbs. (2700 + 1500 max. = 4200).

4. VEHICLE TEST WEIGHT - W_t

$W_t = W_c + 400$ lbs. W_t is the vehicle weight at which all accelerative maneuvers, fuel economy and emissions are to be calculated. (Items 9c,11c,11d,11e, 11f, 12,13).

The maximum allowable test weight, W_{tm}, is 4600 lbs. (2700 + 1500 max. + 400 = 4600).

5. GROSS VEHICLE WEIGHT - W_g

$W_g = W_c + 1100$ lbs. W_g is the gross vehicle weight at which sustained velocity capability at 5 percent and 30 % grades is to be calculated. (Item 11f). The 1100 lbs. load simulates a full load of passengers and baggage.

The maximum allowable gross vehicle weight, W_{gm}, is 5300 lbs. (2700 + 1500 max. + 1100 = 5300).

6. PROPULSION SYSTEM VOLUME - V_p

V_p is the volume allotted for all items identified under item 2. The propulsion system shall be packagable in such a way that the volume encroachment on either the passenger or luggage compartment does not exceed the following:

a) The transmission tunnel may not be widened so as to decrease the selected production vehicle clearance between the accelerator pedal and the tunnel. The accelerator pedal may not be relocated.

b) Intrusion of the tunnel into the passenger side of the vehicle may be increased by a maximum of 1.5 inches.

c) The tunnel height may be increased by a maximum of 2 inches but without affecting the full fore and aft adjustment of the front seat of the vehicle. The front seat may not be raised.

The propulsion system shall not violate the vehicle ground clearance lines as established by the manufacturer of the vehicle used for propulsion system/vehicle packaging. Additionally, the propulsion system shall not violate the space allocated for wheel jounce motions and vehicle steering clearances. Necessary external appearance (styling) changes will be minor in nature. The propulsion system shall also be packagable in such a way that the handling characteristics of the vehicle are not degraded.

7. AIR DRAG

The product of the drag coefficient, C_d, and the frontal area, A_f, is to be used in air drag calculations. The product of C_dA_f has a value of 12 ft^2. The air density used in computations shall correspond to the applicable ambient air temperature.

8. ROLLING RESISTANCE

Rolling resistance, R, is expressed in the equation $R = (W/65)\ [\ 1 + (1.4 \times 10^{-3}V) + (1.2 \times 10^{-5}V^2)\ ]$ lbs. V is the vehicle velocity in ft/sec. W is the vehicle weight in lbs.

9. PROPULSION SYSTEM EMISSIONS

The vehicle is to be tested for emissions in accordance with the procedure in the July 2, 1971 Federal Register and as further described in the Code of Federal Regulations Title 40 Part 85 for model year 1976 light duty vehicles (CFR 40-85). The vehicle test weight shall be W_t and the accessory load as defined in Section 14a. Ambient conditions are 14.7 psia and 85°F. Emission tests will be run with fuel specified in Section 10.

The Federal emissions standards are:

Hydrocarbons	-	0.41	grams/mile maximum
Carbon Monoxide	-	3.40	grams/mile maximum
Oxides of Nitrogen*	-	0.40	grams/mile maximum

Prototype vehicles are to meet the following emissions goals to allow for production tolerances and life degradation. Measurement of emissions is to be taken after the system has operated for 100 hours.

Hydrocarbons	-	0.20	grams/mile maximum
Carbon Monoxide	-	1.70	grams/mile maximum
Oxides of Nitrogen*	-	0.20	grams/mile maximum

*Oxides of nitrogen are to be measured or computed as NO_2

Production of smoke, odors, aldehydes, ammonia, particulates or other undesirable emissions not now specified in the July 2, 1971 Federal Register are undesirable.

10. FUEL

Emission tests will use the fuel specified below, however, the power system shall have the capability of meeting emission levels using commercially available unleaded fuels.

Item	ASTM Designation	Specification
Octane, Research, min.	D1656	91-93
Pb. (Organic), gm/U.S. gal	D 525	< .02
Distillation range	D 86	-
I.B.P., °F	-	100-115
10 percent point, °F	-	140-150
50 percent point, °F	-	240-250
90 percent point, °F	-	330-340
E.P. °F (max)	-	425
Sulfur, Wt. percent max.	D1266	0.10
Phosphorous, theory	-	0.0
R.V.P. lb.	D 323	5.5-7.5
Washed gum (max) mgm/gal	D 381	4.0
Corrosion (not lower than)	D 130	1B
Oxidation stability (not less than)	D 525	240+
Hydrocarbon composition	D1319	-
Olefins, percent, max.	-	30
Aromatics, percent, max.	-	40
Saturates	-	Remainder

For computation purposes the lower heating values of this fuel is to be assumed as 18500 Btu/lb. The cost to be assumed for system cost analysis is $0.31/gallon. An A.P.I. gravity of 56.0 is to be assumed in all calculations.

11. START UP, ACCELERATION, AND GRADE VELOCITY PERFORMANCE

a. Start Up:

The vehicle must be capable of being tested in accordance with the procedure outlined in the July 2, 1971 Federal Register without special driver startup/warmup procedures. The accessory load shall be as defined in Section 14b.

The maximum time from "key on" to reach 65 percent of full power level is 45 sec. Ambient conditions are 14.7 psia 60°F. The vehicle is to be soaked at this temperature for a minimum of 12 hours prior to initiation of start test.

Powerplant starting procedures in low ambient temperatures shall be equivalent to or better than the typical automobile spark-ignition engine. After a 24 hour soak at -20°F and 14.7 psia the engine shall achieve a self-sustaining idle condition without further driver input within 25 seconds. No starting aids external to the normal vehicle system shall be needed at or above - 20°F.

b. Idle operation conditions:

The idle creep torque shall not result in level road operation of the vehicle at a speed in excess of 18 mph in high gear, with the entire propulsion system at steady state operating temperature and ambient conditions of 14.7 psia and 85°F. The accessory load shall be as defined in Section 14a.

c. Acceleration from a standing start:

The minimum distance to be covered in 10.0 sec. is 440 ft. The maximum time to reach a velocity of 60 mph is 13.5 sec. Ambient conditions are 14.7 psia, 85°F. Vehicle weight is W_t and accessory load as defined in Section 14a. Acceleration is on zero grade and initiated with the engine at the normal idle condition.

d. Acceleration in merging traffic:

The maximum time to accelerate from a constant velocity of 25 mph to a velocity of 70 mph is 15.0 sec. Ambient conditions are 14.7 psia, 85°F. Vehicle weight is W_t and accessory load as defined in Section 14a. Acceleration is on zero grade and time starts when the accelerator pedal is depressed.

e. Acceleration, DOT High Speed Pass Maneuver:

The maximum time and distance to go from an initial velocity of 50 mph with the front of the automobile (18 foot length assumed) 100 feet behind the back of a 55 foot truck traveling at a constant 50 mph, to a position where the back of the automobile is 100 feet in front of the front of the 55 foot truck, is 15 sec. and 1400 ft. The entire maneuver takes place in a traffic lane adjacent to the lane in which the truck is operated. Vehicle is accelerated until the maneuver is completed or until a maximum speed of 80 mph is attained, whichever occurs first. Vehicle acceleration ceases when a speed of 80 mph is attained, the maneuver then being completed at a constant 80 mph. (This does not imply a design requirement limiting the maximum vehicle speed to 80 mph). Time starts when the accelerator pedal is depressed. Ambient conditions are 14.7 psia, 85°F. Vehicle weight is W_t and accessory load as defined in Section 14a. Acceleration is on zero grade.

f. Grade velocity:

The vehicle must be capable of starting from rest on a thirty percent (30%) grade and ascending the grade at a minimum speed of 5 mph. The vehicle must be capable of this maneuver in both the forward and reverse directions at a vehicle weight of W_g, with the accessory load as defined in Section 14a.

The minimum cruise velocity that can be continuously maintained on a five percent (5%) grade shall be not less than 65 mph with a vehicle weight of W_g and accessory load as defined in Section 14a.

The minimum cruise velocity that can be continuously maintained on a zero percent (0%) grade shall be not less than 85 mph with a vehicle weight of W_t and with the accessory load as defined in Item 14a.

Ambient conditions for all grade specifications are 14.7 psia and 85°F.

Performance degradation attributable to loss of powerplant efficiency at extreme temperatures shall not exceed ten percent (10%) relative to the performance values specified at 85°F. This limitation applies to ambient temperatures from -20°F to 105°F.

The wind velocity is to be less than 10 mph for all acceleration and grade tests.

12. MINIMUM VEHICLE RANGE

Minimum vehicle range without refueling will be 200 miles (maximum fuel capacity is 25 U.S. gallons). The minimum range shall be calculated for, and applied to each of the following modes:

1. Cyclic mode is: The Federal driving cycle which is in accordance with the July 2, 1971 Federal Register. The range may be calculated for one cycle and ratioed to 200 miles.

2. Cruise mode is: A constant 70 mph cruise on a zero grade for 200 miles.

The vehicle weight for both modes shall be W_t initially and with accessory power levels as specified in Section 14 . The ambient conditions shall be a pressure of 14.7 psia, and a temperature of -20°F (air conditioner off) and 105°F (air conditioner on).

13. FUEL CONSUMPTION

Using the fuel specified in Section 10,a "fuel economy" figure shall be calculated based on 1) miles per gallon and 2) the number of Btu per mile required to drive the vehicle through the following modes of operation:

	Avg. Speed	Hours	% of Time
1) Federal Driving Cycle	19.84	1750	50
2) Simplified Surburban Route (equal times at constant 20,30 and 40 mph speeds).	30.00	1150	33
3) Simplified Country Route (equal times at constant 50,60 and 70 mph speeds).	60.00	600	17
Totals	30	3500	100

In all cases the system fuel consumption shall be calculated for a vehicle weight of W_t initially, and power levels as specified in item 14a. Ambient conditions are 14.7 psia and 85°F.

It is desirable that the fuel consumption rate at idle operating condition not exceed 7 lbs/hour.

14. ACCESSORY POWER REQUIREMENTS

a. Accessory power requirements with the air conditioning in operation are defined as 15 hp at maximum engine speed and 4 hp at engine idle speed, with a linear relationship between these two points.

b. Accessory power requirements without the air conditioning in operation are defined as 5 hp at maximum engine speed and 2 hp at engine idle speed, with a linear relationship between these two points.

15. PROPULSION SYSTEM OPERATING TEMPERATURE AND PRESSURE RANGE

The propulsion system shall be operable within an expected ambient temperature range of -40° to 125°F.

The propulsion system shall be operable within an expected environmental pressure range of 9 psia to 15 psia.

16. PASSENGER COMFORT REQUIREMENTS

Heating and air conditioning of the passenger compartment shall be at a rate equivalent to that provided in the present (1970) standard full size family car.

Present practice for maximum passenger compartment heating rate is approximately 30,000 Btu/hr. For an air conditioning system at 110°F ambient, 80°F and 40% relative humidity air to the evaporator, the rate is approximately 13,000 Btu/hr.

17. NOISE STANDARDS

a. Maximum noise test:*

The maximum noise generated by the vehicle shall not exceed 77 dbA when measured in accordance with SAE J986a. Note that the noise level is 77 dbA whereas in the SAE J986 the level is 86 dbA.

b. Low speed noise test:*

The maximum noise generated by the vehicle shall not exceed 63 dbA when measured in accordance with SAE J986a except that a constant vehicle velocity of 30 mph is used on the pass-by.

c. Idle noise test:*

The maximum noise generated by the vehicle shall not exceed 62 dbA when measured in accordance with SAE J986a except that the engine is idling (clutch disengaged or in neutral gear) and the vehicle is stationary. A 360° survey shall be made, the microphone being 10 feet from the vehicle perimeter.

* The air conditioner will not be in operation during noise tests.

18. OPERATIONAL LIFE

The design lifetime of the propulsion system in normal operation will be 3500 hours minimum.

Termination of the operational life of an engine shall be determined by structural or functional failure. Functional failure is defined as power degradation exceeding 25 percent of maximum output of the rear wheels.

19. RELIABILITY AND MAINTAINABILITY

The reliability and maintainability of the vehicle shall equal or exceed that of the spark-ignition automobile. The mean-time-between-failure should be maximized to reduce the number of unscheduled service trips. No failure modes shall present a serious safety hazard during vehicle operation and servicing. Failure propagation should be minimized. The power plant should be designed for ease of maintenance and repairs to minimize costs, maintenance personnel education, and downtime.

20. COST OF OWNERSHIP

The initial cost and net cost of ownership of the vehicle shall be minimized for ten years and 105,000 miles of operation.

21. SAFETY STANDARDS

The vehicle shall comply with all Department of Transportation Federal Motor Vehicle Safety Standards in force when the selected test vehicle was manufactured.

TABLE I

TEST CONDITIONS
(ENGINE DYNAMOMETER, CHASSIS DYNAMOMETER, ROAD)

Section	Performance Requirements	Accessory Power	Weight	Temperature	Pressure
9. EMISSIONS	HC 0.20 grams per mile**	14a	W_t	85°F	14.7
	CO 1.70 grams per mile**	14a	W_t	85°F	14.7
	NO_2 0.20 grams per mile**	14a	W_t	85°F	14.7
11. PERFORMANCE					
a. Start Up	65%* power in 45 sec**	14b	W_t	60°F	14.7
	Driver Assistance 25 sec**	14b	W_t	-20°F	14.7
b. Idle	Creep 18 mph**	14a	W_t	85°F	14.7
c. Accel (0-60)	13.5 sec** to 60 MPH	14a	W_t	85°F	14.7
	440 ft* in 10.0 sec.	14a	W_t	85°F	14.7
d. Accel (25-70)	15.0 sec** from 25 to 70 MPH	14a	W_t	85°F	14.7
e. Accel (50-80)	15.0 sec** and 1400 Ft** From 50 to 80 MPH**	14a	W_t	85°F	14.7
f. Grade (30%)	0 to 5 MPH*	14a	W_g	85°F	14.7
(5%)	65 MPH*	14a	W_g	85°F	14.7
(0%)	85 MPH*	14a	W_t	85°F	14.7
12. VEHICLE RANGE	200 MI*				
	1. During FCE	14b and 14a	W_t	-20°F and 105°F	14.7
	2. At 70 MPH	14b and 14a	W_t	-20°F and 105°F	14.7
13. FUEL CONSUM.	MPG During FDC	14a	W_t	85°F	14.7
	MPG at 20,30, and 40 MPH	14a	W_t	85°F	14.7
	MPG at 50,60, and 70 MPH	14a	W_t	85°F	14.7

NOTES: Emission tests will be run with fuel specified in Section 10.
Road test wind conditions shall not exceed 10 MPH in any direction.
*Minimum values
**Maximum values